

PD Connection with National Underground Lab

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Fermilab

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Outline

- Introduction : A Brief Review of the saga of building a National Underground Laboratory
- Recent developments
- What's DUSEL?
 - Scope and Process
- The Accelerator Connection
- Summary & Outlook

History...

- 1965 : construction of the Davis,et.al. Cl detector begins at the Homestake Mine
 - Over the next 35 years Homestake hosts the Cl experiment,as well as cosmic and double- β experiments
- Early 1980's: Al Mann and collaborators lead an effort to create a US underground science laboratory, modeled after the newly started Gran Sasso Laboratory in Europe. Despite growing excitement in the community over solar neutrinos, double beta decay, proton decay and other underground science, the funding effort is unsuccessful.
 - Over the next decade, proton decay experiments are started in the US at Soudan and IMB; worldwide underground initiatives continue
- 1998-1999 : New discussions begin with NSF and DOE about establishing Homestake as a national underground science laboratory.

History, con't

- 2000
 - DOE sponsored workshop on using WIPP (Waste Isolation Pilot Plant, Carlsbad, N.M.) as a site for a next-generation underground laboratory
 - Underground Laboratories included as one of five working groups in the nuclear physics community's NSAC Long Range Planning meeting
 - Presentations for Homestake, WIPP and Soudan in US, as well as Gran Sasso, Kamioka and Sudbury
 - NSF suggests the development of a White Paper supporting the creation of a National Underground Science Laboratory (NUSL)
 - Bahcall Committee : Bahcall, Barish, Calaprice, Conrad, Doe, Gaisser, Haxton, Lesko, Marshak, Robinson, Sadoulet, Sobel, Wiescher, Wojcicki, Wilkerson

White Paper on Underground Science

I. Solar Neutrinos

II. Double Beta Decay

III. Dark Matter

IV. Nucleon Decay

V. Atmospheric Neutrinos

VI. LBL ν oscillations

VII. Supernova neutrinos

VIII. Nuclear Astrophysics

IX. Geoscience

X. Materials Development and Technology

XI. Monitoring Nuclear Tests

XII. Microbiology

Common
Detector?

FNAL to

Soudan - 730km

Homestake - 1340km

WIPP - 1800km

San Jacinto - 2680km

Report of the Technical Subcommittee

- 4 sites investigated
 - Homestake (up to 7200 mwe)
 - San Jacinto (horizontal access, 6,500 mwe)
 - Carlsbad (WIPP) (1700 existing mwe)
 - Soudan (2200 mwe existing)
- Homestake & San Jacinto favored for depth
- Many other factors considered and documented
 - i.e. Soudan in “existing” neutrino beam, although already recognized that a longer baseline may be desirable

Subsequent reviews over the next several years come to similar conclusions

History con't

March 2001 - Nuclear Physics Long Range Plan :

“We strongly recommend immediate construction of the world’s deepest underground science laboratory. This laboratory will provide a compelling opportunity for nuclear scientists to explore fundamental questions in neutrino physics and astrophysics.”

June 2001 - NUSL-Homestake proposal submitted to the NSF

July 2001 - High Energy Physics community includes
Underground Science in Snowmass summer study

October 2001 - Lead Workshop(s) on Underground Science
Science and engineering workshops

History con't :

Committee Reports by and for Funding Agencies

- Nuclear Science Advisory Committee(NSAC) : Opportunities in Nuclear Science: *A Long Range Plan for the Next Decade* (April 2002)
- High Energy Physics Advisory Panel (HEPAP): *The Way to Discovery : Particle Physics in the 21st Century* (April 2002)
- National Research Council (NRC): *Connecting Quarks to the Cosmos : Eleven Science Questions for the New Century* (April 2002)
- Nuclear Facilities Assessment Committee (NRC panel): *Neutrinos and Beyond* (December 2002)

2003 : Detailed proposals for Homestake, Soudan and San Jacinto submitted to NSF

- National Science and Technology Council (NSTC/OSTP) : *A 21st Century Frontier of Discovery : The Physics of the Universe* (February 2004)
- NSF/DoE Office of Science HEPAP committee: *The Quantum Universe* (June 2004)

All the reports send ~ the same message;
from *Neutrinos and Beyond*

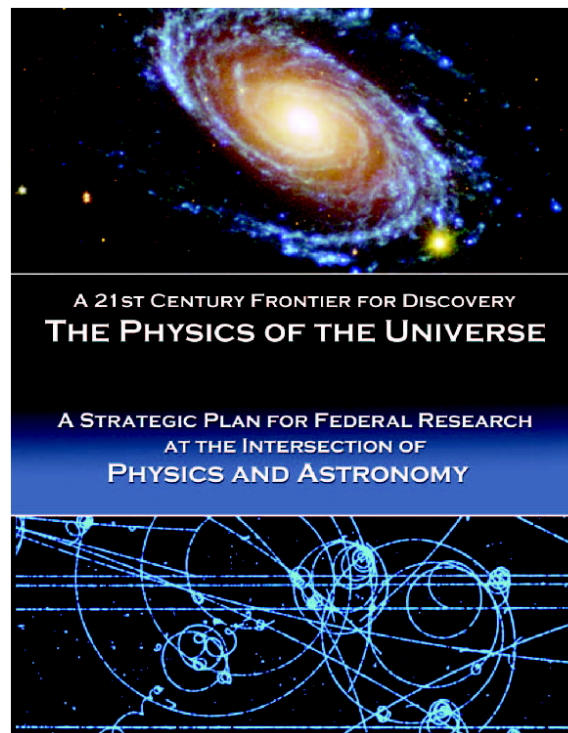
For a deep underground facility, the report discusses a broad array of potential experiments (some to be done in the very long term). Some of these can and certainly will be undertaken elsewhere in the world. However, at this time, the experiments themselves, as well as the programs in the major facilities elsewhere in the world, are yet to be defined. Therefore, the committee focused on determining the requirements for such experiments (e.g., size, depth, distance from accelerator facilities) and what the advantages of a deep underground laboratory in the United States might be for some of the science planned. It could draw only limited

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Scientists addressing issues of intense international interest—solar neutrinos, double beta decay, and dark matter—are poised to develop next-generation detectors that require low background, and they need an underground facility for technology development in the next few years. Once the neutrino mixing and mass parameters have been measured with some accuracy, a long-baseline experiment should be developed. The KamLAND, Borexino, MiniBooNE, and MINOS experiments are expected to lead—over the next 5 years—to the synthesis necessary for the long-baseline program. A long-baseline target detector is likely to also carry out a proton decay experiment and serve as a supernova neutrino telescope, as well as many other purposes.

NSF Site Panel Report Concerning a Deep, Underground Science and Engineering Laboratory - 5/28/03

- Evaluation of
 - Geological suitability
 - ~50 m linear dimension, ~2500 m depth, ~50 yr use
 - Relative costs
 - Access, excavation, infrastructure
- 3 Sites Reviewed
 - Homestake Mine, Lead, SD
 - Soudan Mine, Soudan, Mn
 - Mt. San Jacinto, Ca
- Conclusion
 - Most favorable : Homestake
 - Least Favorable : San Jacinto
 - Possible “back-up” : Soudan



February 2004

Dark Matter, Neutrinos, and Proton Decay

- * NSF will be the lead agency for concept development for an underground facility. NSF will develop a roadmap for underground science by the end of 2004.
- * NSF and DOE will work together to identify a core suite of physics experiments. This will include research and development needs for specific experiments, associated technology needs, physical specifications, and preliminary cost estimates.

About this Report

In this report the Interagency Working Group on the Physics of the Universe responds to the National Research Council's (NRC) 2002 report, *Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century*. The Physics of the Universe group examines the status of the Federal government's current investments aimed at answering the eleven questions in the NRC report. Based upon that assessment, the group prioritized the new facilities needed to advance understanding in each of these areas. Consistent with a goal of the President's Management Agenda to manage Federal R&D investments as a portfolio of interconnected activities, this report lays out a plan for exciting discovery at the intersection of physics and astronomy.

Theme 2: Dark Matter, Neutrinos, and Proton Decay

The most suitable environment for many of the experiments is deep underground, where the surface layers of the earth itself provide the necessary overburden for shielding. In addition, significant savings could be gained since many experimental detectors could be used for multiple scientific purposes. There are several underground facilities available today such as the Soudan Mine in Minnesota, Sudbury Neutrino Observatory (SNO) near Ontario, Canada, the Gran Sasso in Italy, the Kamioka mine in Japan and the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. Several other potential sites are currently being explored, as well.

The next generation of proton decay experiments does not require extreme depths, but does require very large volumes of water, and hence, laboratory space. The next generation proton decay detectors would need a mass approaching the equivalent of a megaton of water. Such detectors have a “dual use” and could also serve as neutrino detectors for long-baseline neutrino oscillation studies and simultaneously allow the study of neutrino bursts from supernovae.

Meanwhile...

- Earth scientists begin discussing opportunity to develop an underground research laboratory in conjunction with proposals to create an underground neutrino observatory.
- October 2001 - Earth Science Workshop to discuss earth science studies that could be conducted at the underground lab and discuss the technical requirements for such studies
- June 2003 - *Earthlab : A Subterranean Laboratory and Observatory to Study Microbial Life, Fluid flow, and Rock Deformation*, June 2003.
- September 2003 - An NSF-Sponsored Workshop on Deep Underground Science and Engineering Laboratories (DUSELs) [in conjunction with 10th Congress of the International Society of Rock Mechanics]
 - The workshop was convened to refine the scope of activities proposed at Earthlab, an underground research laboratory that may be developed in conjunction with a deep neutrino detector.

More recently....

- NSF returns unsolicited Homestake, Soudan and San Jacinto proposals “without predjudice” February 2004
- 29 March 2004 Process Meeting at NSF
 - **NSF/MPS**-led, working with **GEO**, **ENG** and **BIO** Directorates through an Underground Science Working Group
 - NSF Working with DOE to develop mechanisms for reviewing and funding experiments
 - Series of 3 solicitations to help the community develop proposal(s)
 - #1 Science motivation, experimental programs, synergies, site-independent definition of requirements
 - #2 Site specific investigation of suitability of a site to meet requirements defined in #1
 - #3 Site specific proposals
- Currently 8 candidate sites



National Science Foundation

Directorate for Mathematical and Physical Sciences

Division of Physics

Directorate for Geosciences

Division of Earth Sciences

Directorate for Engineering

Division of Civil and Mechanical Systems

Solicitation #1 proposals due 9/15/04

Program Title:

Deep Underground Science and Engineering Program Planning and Technical Requirements

Synopsis of Program:

This solicitation invites proposals to develop the scientific and engineering objectives and technical requirements for any areas of science and engineering that require the special characteristics of a deep underground environment. The separate Elements (experiments) should be grouped in Modules (groups of experiments that share basic infrastructural requirements) for a possible deep underground science and engineering laboratory. The primary purpose of this solicitation is to establish the site-independent scientific and engineering benchmarks against which the capabilities of the candidate sites for an underground laboratory will be measured. The Elements within each Module may be grouped by required depth, required space, by scientific or engineering area, or by other unifying features. Potential spatial or other infrastructural incompatibilities between individual elements should also be identified.

Award Information

- **Anticipated Type of Award:** Standard Grant
- **Estimated Number of Awards:** 1 to 3
- **Anticipated Funding Amount:** \$500,000 -- Up to a total of \$500,000 subject to availability of funds.

II. PROGRAM DESCRIPTION

This solicitation is the first in a series of three that will provide the underpinnings for a decision on creating an infrastructure for underground science and engineering and enabling an initial set of experiments. It invites proposals to:

- (1) Develop the scientific and engineering case for the range of potential experiments needing underground access (the Elements);
- (2) Describe the associated technical requirements on the infrastructure and instrumentation; and
- (3) Group the Elements with similar scientific motivation and associated technical requirements for infrastructure into Modules.

Emphasis on finding synergies

NSF will consider proposals to develop Modules incorporating relevant areas of physics, astrophysics, geosciences, engineering, microbiology, manufacturing, defense-related areas, and any other areas of science and engineering that require the special characteristics of an underground environment. The reports cited above indicate that the following Modules would be an appropriate starting point: “deep” physics; “large” physics; engineering; biology; geophysics; national security; and “other.”

Awards made under this solicitation will establish the scientific and engineering case for underground laboratory infrastructure and the site-independent science and engineering benchmarks against which the capabilities of candidate sites for a laboratory will be measured. Thus, it is essential that the entire community of scientists and engineers who might develop experiments for an underground facility be involved in the process. Those responding to the solicitation are encouraged to combine forces so as to generate a complete interdisciplinary representation of the underground science and engineering spectrum.



Principal Investigator: Bernard Sadoulet

Professor of Physics, University of California at Berkeley

Director, UC Institute for Nuclear and Particle Astrophysics and Cosmology

Co-Investigators:

Eugene Beier, Professor of Physics, University of Pennsylvania

Charles Fairhurst, Professor of Civil Engineering, University of Minnesota

Tullis Onstott, Professor of Geosciences, Princeton University

Hamish Robertson, Professor of Physics, University of Washington

James Tiedje, Professor of Microbiology, Michigan State University

*For Solicitation 1, attempt to develop a single
Proposal within the community*



Solicitation 1 Workshop at Berkeley

August 11-14, 2004

Science Working Groups

- 1) Solar Neutrinos: Tom Bowles (LBNL) and Bruce Vogelaar (Virginia Tech)
- 2) Double Beta: John Wilkerson (U. of Washington) and TBD
- 3) Long baseline experiments: Milind Diwan (BNL) and Gina Rameika (Fermilab)
- 4) Nucleon Decay/atmospheric neutrinos: Hank Sobel (UC Irvine) and Chang-Kee Jung (Stony Brook)
- 5) Dark Matter: Dan Akerib (Case Western and Reserve) and Elena Aprile (Columbia)
- 6) Hydrology and coupled processes: Brian McPherson (U New Mexico), Eric Sonnenthal (LBNL)
- 7) Geochemistry: water rock interactions: TBD
- 8) Rock mechanics/seismology: Larry Costin (Sandia), Paul Young (U. of Toronto)
- 9) Applications: homeland security, storage (waste disposal, oil, carbon sequestration): Francois Heuzé (LLNL), Jean Claude Roegiers (U. of Oklahoma)
- 10) Biogeology methodology (Determining sampling objectives & sites, sampling strategies, contamination control, enhanced methodologies for biomarker analysis) Tommy Phelps, (Oak Ridge), Tom Kieft (Mexico Tech)
- 11) Micro and molecular biology (Microbial diversity, physiology, activity and molecular evolution): Jim Fredrickson (Pacific Northwest), TBD
- 12) Low background counting facilities and prototyping (pre-DUSEL and at DUSEL): Prisca Cushman (U. Minnesota) and Harry Miley (Pacific Northwest Lab)
- 13) Education and Outreach: Willi Chinowski, (LBL) Susan Pfiffner (U. of Tennessee) + [Laboratory Astrophysics/Accelerators](#)

Sites developing DUSEL Solicitation #2 proposals

INDIVIDUAL SITES

Cascades–Ice Creek, WA, <http://mocha.phys.washington.edu/NUSEL/icle.html>

Henderson Mine, CO, <http://cause.mines.edu/>

Homestake Mine Project, SD, <http://www.hpcnet.org/homestake#>; and
<http://ktlesko.lbl.gov/nusel>

Kimballton Mine, VA, <http://www.phys.vt.edu/~kimballton/>

Mt. San Jacinto, CA, <http://www.ps.uci.edu/~SJNUSL/>

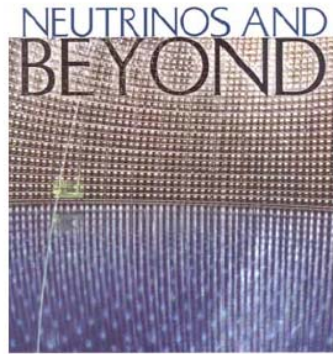
Soudan Mine, MN, <http://www.soudan.umn.edu/NUSEL/>

The Sudbury Neutrino Observatory Laboratory (SNOLAB), Ont., <http://www.snolab.ca>

WIPP (Waste Isolation Pilot Plan), NM, <http://www.wipp.ws/science/index.htm>

Green Fields Report, http://ktlesko.lbl.gov/NUSEL/green_fields.pdf

The accelerator connection



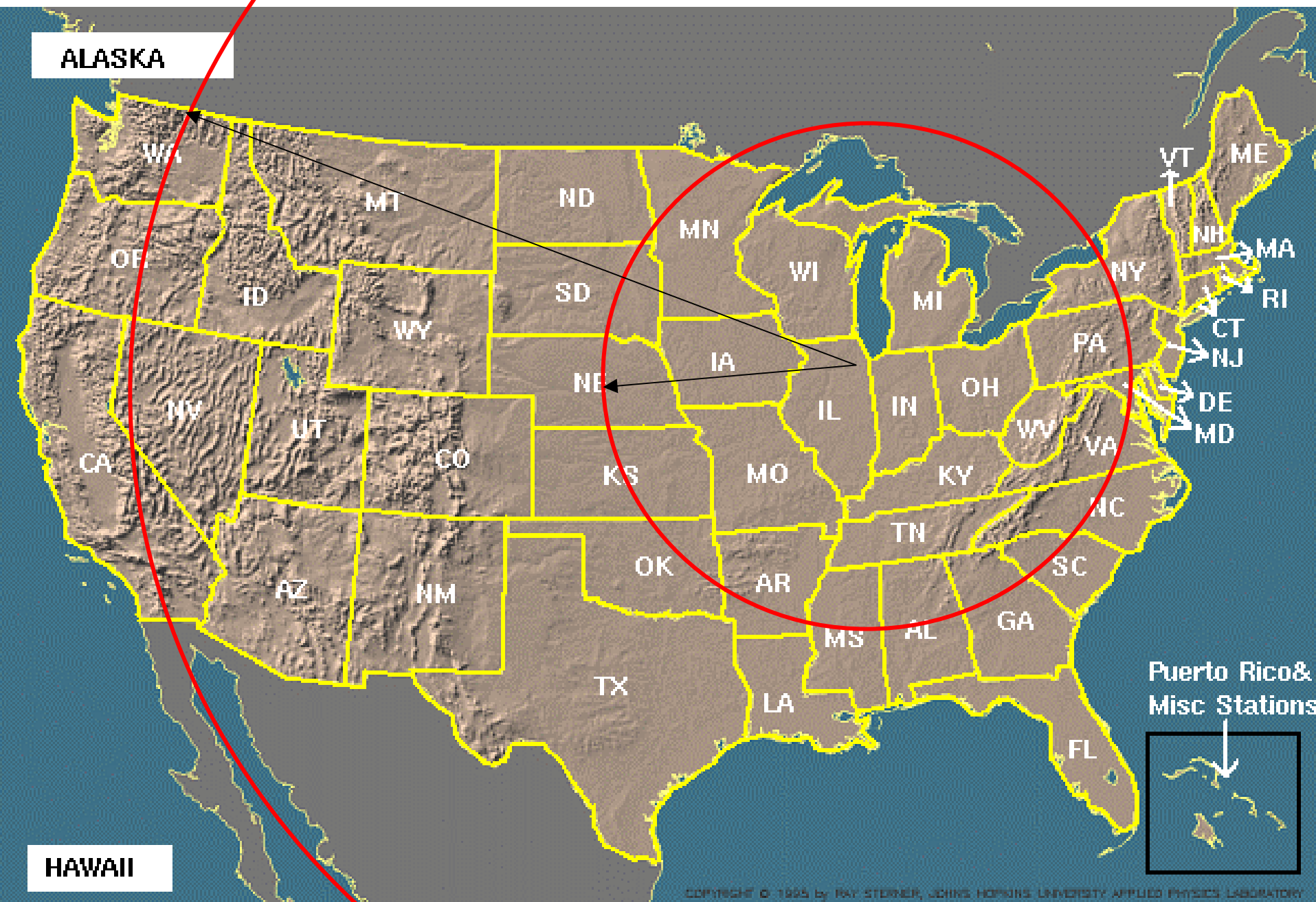
New Windows on Nature

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trino energies higher than 1 GeV, the optimal distances are longer than about 500 km, depending on the exact value of the mass splitting, which will be determined in the next few years. Since the probability of oscillation is small and the fraction of the neutrino beam intercepted by the target decreases with distance, very high fluxes of neutrinos will be required. If measuring θ_{13} goes reasonably well, measuring the mass hierarchy and the CP properties of the neutrino admixtures will be compelling. For these goals, the massive target/detectors and high-flux sources will have to be more substantial. It has been shown that it is not easy to disentangle effects of θ_{13} , different mass hierarchies, and CP violation, because all of them affect the oscillation probabilities simultaneously. Researchers will need at least two different baselines and/or energies to resolve each of them separately. In Japan and Europe, the baselines currently envisaged are relatively short. Therefore it makes sense to develop plans for experiments with baselines longer than 1,000 km in the United States in the context of the international program. Indeed, distances from the two major proton laboratories (Fermilab and Brookhaven) range from 1,200 to 2,600 km for the several proposed underground sites.

$$1000 \text{ km} < L < 2500 \text{ km}$$

ALASKA

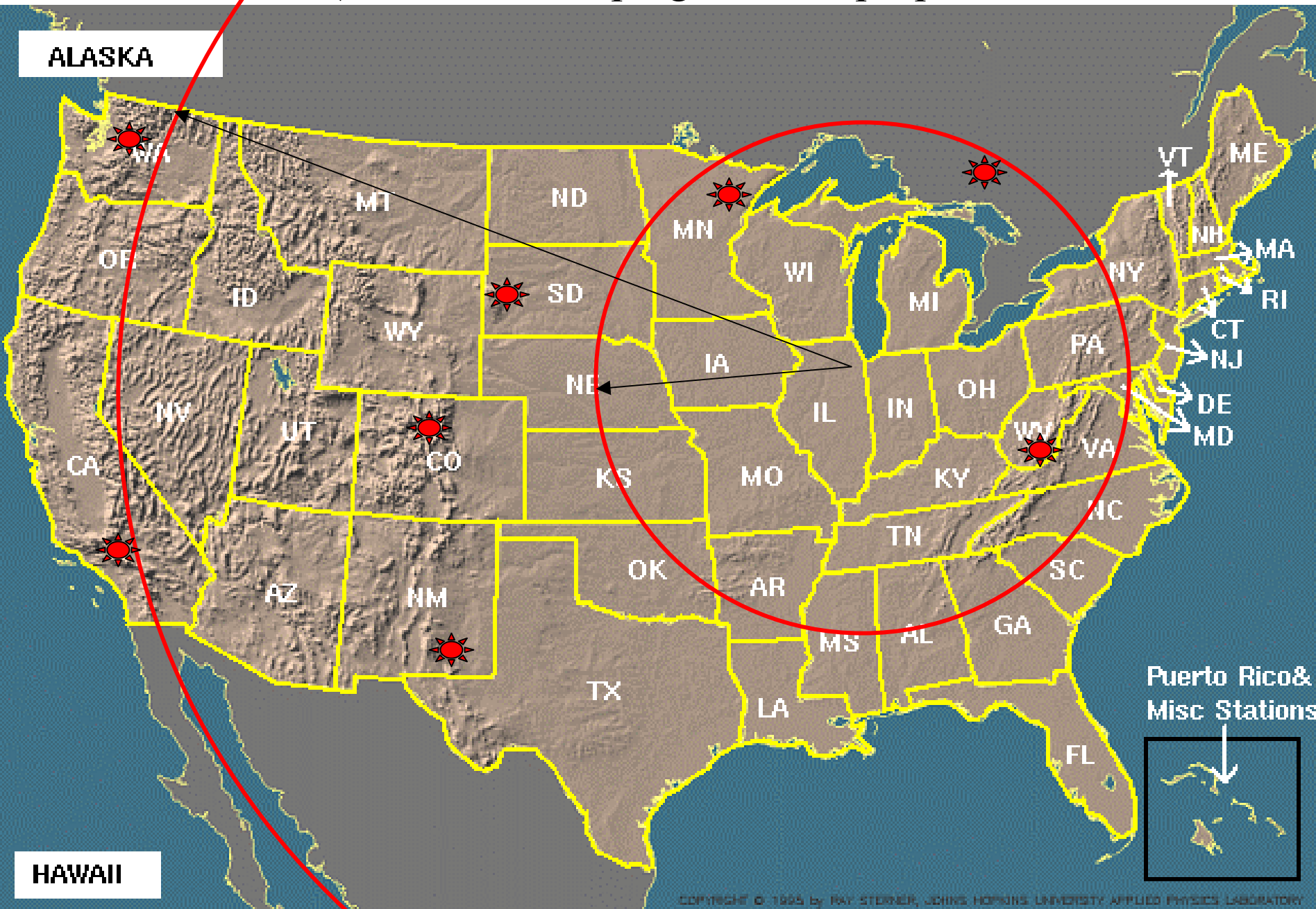


HAWAII

Puerto Rico &
Misc Stations

☀ Sites developing DUSEL proposals

ALASKA

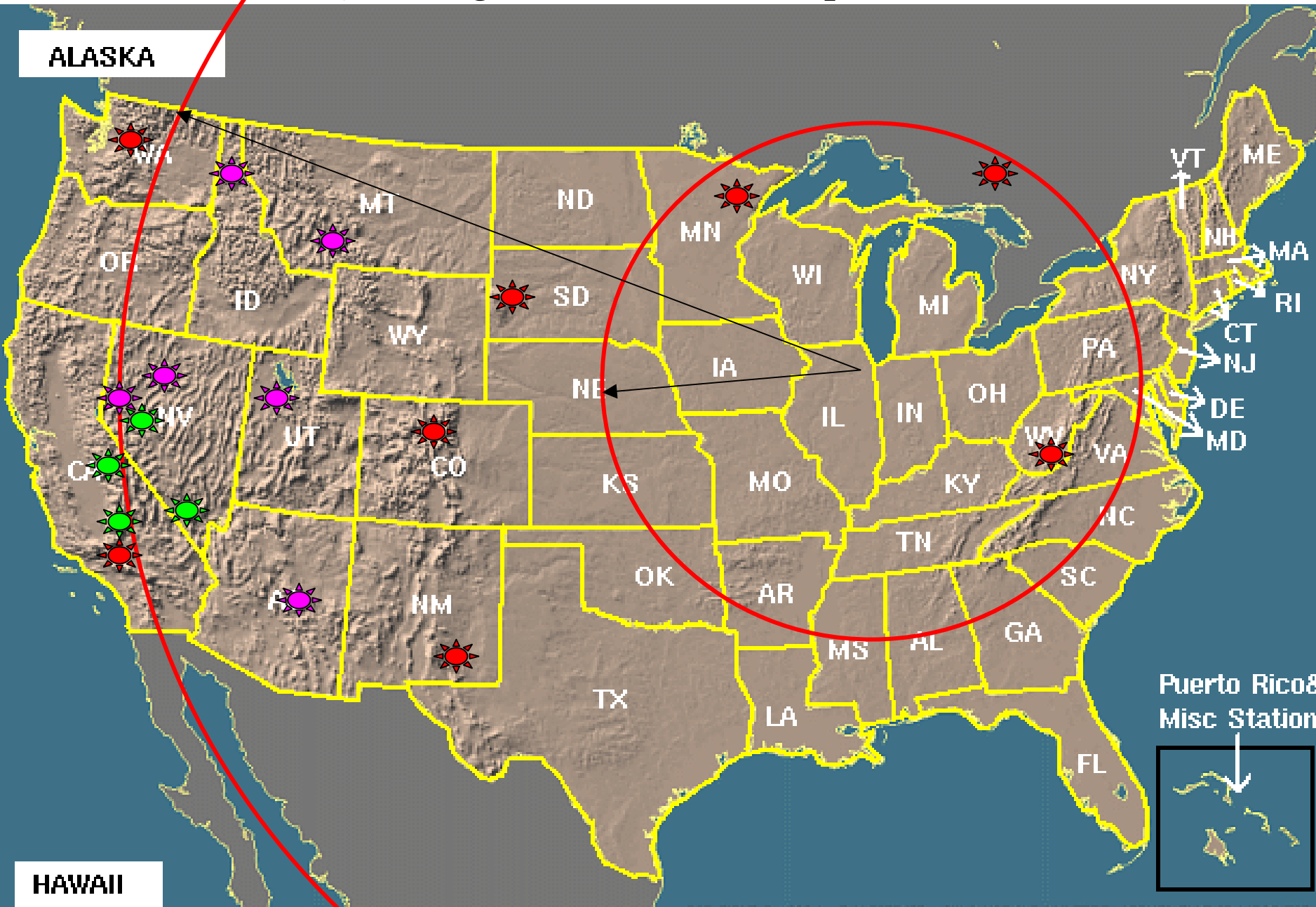


HAWAII

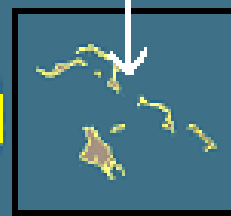
Puerto Rico &
Misc Stations

☀ Laughton “additional” potential sites

ALASKA



Puerto Rico & Misc Stations

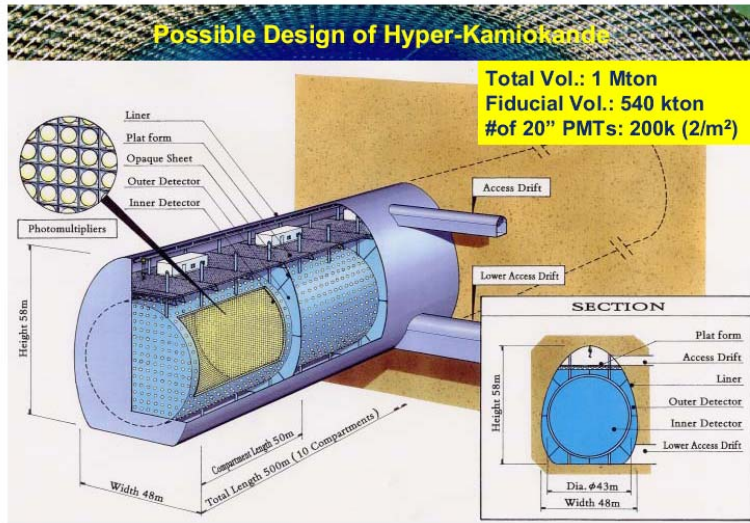


HAWAII

Flavor of the Workshop

- Exploration of Modules and Synergies
 - LBL & Proton decay detectors
 - Large → good synergy
 - Similar depth requirement : not necessarily
 - Large detectors *vs* small detectors
 - Deep *vs* very deep
 - Large caverns *vs* small caverns → \$\$\$ issue
 - Geoscience *vs* Physics
 - Homogeneous *vs* varied rocks
 - Geoscientist may benefit most from the site investigation process if they can get organized promptly
 - Drilling & blasting *vs* running detectors
 - Laboratory Infrastructure
 - Amenities (dormitories, networks,shops...)
 - Outreach

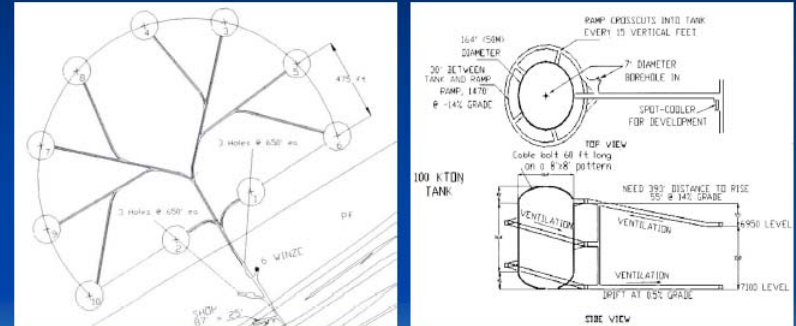
Detector vs Cavern Size



NAS-NFAC meeting, 7/25/02

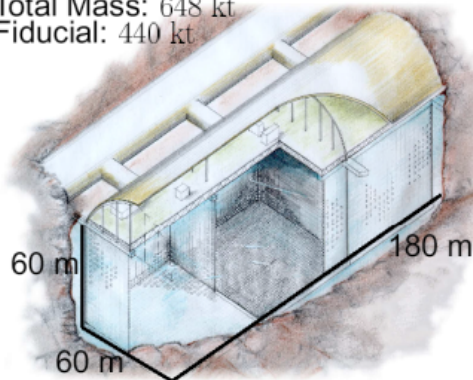
C.K.Jung

Megaton Modular Multi-purpose Detector



UNO Baseline Design

Total Mass: 648 kt
Fiducial: 440 kt



Rock mechanics experts have real reservations about spans of ~100m dimension and >~5000 ft depths;
i.e. Hard to guarantee long lifetime

Time Table

Sept 15 Proposal

15-25 pages

Working group three quarter of page August 20

Scientific case/road map, Open questions, focus of the study

Continuing work on infrastructure in order to have impact on solicitations

Infrastructure requirement matrix: October <==Has not worked well in past

Official approval Dec 1? Proceed in any case

Proposed workshops

Denver Jan 05

Further integration of Earth Sciences and Physics
Modules

Washington DC Mar 05

Conclusions
Participation of agencies

Final report \approx 50 pages + web

External review (NRC style)

Requirements Matrix

Experiment	Category	Depth / Shielding (mwe)	Space, area or volume (m ² or m ³) l*w*h unless specified	Radon Background (mBq/m ³)	Hazardous Materials	Ventilation	Stable Temp. (A/C Req.)	Electrical Power (kW)	"Clean" Areas (class)	Special/Additional Facilities
MOON	Solar neutrino	>2500	11x8x6	10	Toxic, flammable liquids/cryogenics			80	Yes	
LENS	Solar neutrino	>3800	16x16x16	1	Flammable scintillation			250	Yes	
HYBRID	Solar neutrino	7000	80x18x19	None	None			Modest	No	
HERON	Solar neutrino	4500	m radius, 20m high cy	None	Large volume cryogenics			600 Peak, 125 Avg.	Yes	
CLEAN	Solar neutrino	4500	5m radius, 20m high c	None	Large volume			100 Avg.	Yes	
TPC	Solar neutrino	~2500	30x21x21	1	High pressure gas/cryogenics			70 Avg.	No	
Majorana	Double beta decay		5x4x3 m ³	<1000000	Rn, acids & plating baths from Cu electroforming		Yes	10 to 25	Yes	UG Cu electroforming facility, UG Ge crystal growth & detector, machine shop, low level counting, Rn-free matl. Storage, DI water system
			4x4x3 m ³							
EXO	Double beta decay		5x5x5 m ³	<1000000	Large volume liquid xenon/cryogenics, Rn		Yes	10 to 25	Yes	Xenon containment, cryogenic purification system, machine shop, low level counting, Rn-free matl. Storage, DI water system
			4x4x3 m ³							
MOON	Double beta decay		5x8x5 m ³	<1000000	Rn		Yes	10 to 25	Yes	Machine shop, low level counting, Rn-free matl. Storage, DI water system
			8x11x6 m ³							

Depth, volume, ...

Summary

- The scientific case for construction of a National Underground Laboratory to host a diverse set of experiments has been made repeatedly for many years
- The scientific case for planning the next generation of long baseline neutrino oscillation experiments continues to get stronger
- It is well recognized that both of these endeavors are very expensive :
 - Proposals for the Underground Laboratory have had cost estimates which range from ~\$500K - ~\$300M (excluding detectors and very large caverns) depending on the amount of excavation and depths required
- It is therefore also recognized that if we go with the large multi-purpose facility the Laboratory will not get constructed “quickly”
 - Experiments to use the Laboratory will likely be the next-next generation of experiments : experimental goals and hence requirements need to be set accordingly (need to look ahead and know how to plan the science)

Summary con't

- The current DUSEL Process is prescriptive and requires development of “Science Modules”, i.e. a plan for evolution of the DUSEL, perhaps building it in stages
- Multiple Laboratory sites are possible (i.e. it may not be possible to find compatibility among all current proponents and potential users; NSF wants the options explored before making a multiple site decision)
- The *possible* synergy between a detector planned for a long baseline experiment and one planned for proton decay and supernova observation is recognized by both the scientific communities planning the experiments as well as those who review the scientific proposals and policy makers/funding agencies
- There is not a complete consensus among the DUSEL proponents that a very large detector + neutrino beam is in fact the “flag ship” experiment of the Laboratory (large vs small camps)

Summary con't

- Many potential sites are at appropriate distances from Fermilab (and Brookhaven)
- Most are due West of Fermilab (and BNL)
- Acknowledged that LBL experiment in the DUSEL assumes that the accelerator lab producing the neutrinos will successfully manage to get an upgrade to produce a 1 - 2 MW proton beam.
- Laboratory and detector requirements
 - Deep depth not a requirement for accelerator experiments but is a requirement for proton decay
 - Depth vs cavern size is an important consideration
 - Large/massive detector required for both
 - Water cerenkov - default/baseline because of previous experience
 - Liquid argon - viewed favorably by both communities;
 - Both need R&D to scale to very large size

Conclusions

- Future Long Baseline experiments need the proton driver : > 1 MW proton power
- Future Long Baseline experiments should have a Long Baseline : > 1000 km
- Future Long Baseline experiments need a very massive detector : $>> 50$ ktons
- Future $\Rightarrow >\approx 10$ years

Conclusions

- Now is the time to
 - Get started with getting the Proton Driver approved
 - Learn how to handle MW proton beams : heating and radiation protection issues
 - Work on optimizing proton energy/neutrino flux; develop conceptual designs for extraction and neutrino beam components
 - These may have impacts on layouts of the proton driver which need to be addressed early due to environmental impact analysis (one of the earliest steps in getting a new start approved)
 - Evaluate appropriate sites; work with the on going process for site selection of an Underground Laboratory; decide if the synergy is real and workable
 - Continue/increase detector R&D to enable the design of an appropriate, cost & technically efficient detector